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LIGHT REFLECTIVE FILM AND LIGHT EMITTING APPARATUS

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to a light reflective film and a light-emitting apparatus and, more particularly, to a light reflective film especially suited for forming a light-emitting apparatus comprising a light source such as fluorescent tube, cold cathode tube or the like, and a light-emitting apparatus formed by using such a light reflective film.

BACKGROUND OF THE INVENTION

As is well known, light sources comprising a high frequency current light emitter such as fluorescent tube, cold cathode tube or the like are widely used for indoor and outdoor illumination including back light for liquid crystal display apparatus. Such a light source is required to radiate light with a proper directivity and high intensity in accordance to the operating conditions. To meet these requirements, such light sources are used that have a reflecting device provided behind thereof, reflector fluorescent tube coated with a reflective film therein and aperture fluorescent tube.

A typical example of reflecting device of the prior art used in combination with a light source comprising the high-frequency current light emitter is a reflector plate or the like, that is disposed at a predetermined distance (normally at least 1 mm) apart from the light source. This is because the reflective surface of the reflecting device normally comprises the surface of a metal layer which may cause leakage of high-frequency current when disposed in proximity of the fluorescent tube or the like.

Light sources having reflecting device incorporated therein are also known such as reflector fluorescent tube (e.g. FL30SRW, manufactured by NEC Home Electronics Co., Ltd.) and aperture fluorescent tube (e.g. FL32SAD70, manufactured by NEC Home Electronics Co., Ltd.). For example, the reflector fluorescent tube described above has a reflective film intimately contacted with the inner peripheral surface of a light-transmittive glass tube in such a manner that about two thirds of the inner peripheral surface (equivalent to about 240° in angle of coverage) is covered with the film and further a phosphor is coated over the entire inner peripheral surface of the glass tube. In this fluorescent tube, the phosphor emits light due to vacuum discharge in the glass tube, and

light is guided to the outside solely through the portion of the glass tube that is not covered with the light reflective film. The aperture tube has a light reflective film intimately contacted with the inner peripheral surface of a glass tube in such a manner that about four fifth of the inner peripheral surface is covered with the film, while only the inner peripheral surface of the light reflective film is coated with phosphor and an aperture surface having no light reflective film and no phosphor is provided. Light is emitted through the aperture surface with increased directivity because the light is not diffused by the phosphor.

As described previously, the reflective surface of the reflecting device is usually formed from a metal film, a sheet, vapor-deposited film or the like. This is because the metal surface has relatively high reflectivity and is capable of providing the so-called mirror reflection, thus making it easy to improve the directivity of reflected light. Use of a dielectric reflector is also known for the purpose of effectively improving the light reflectivity on the surface without using a metal. For example, Japanese National Publication (Kohyo) Nos. 9-506837, 9-506984 and 9-511844 (T2) disclose a dielectric reflective film formed by alternately laminating first and second layers which include dielectric materials having different indices of refraction.

Such a dielectric reflective film is formed by placing a plurality of dielectric layers as described above in intimate contact with each other, with thickness and refractive index being in particular relationship so that specific wavelength selectivity (to transmit light of particular wavelength and reflect light of other wavelengths) is provided. The wavelength selectivity is achieved by making use of the principle of wavelength-selective reflection (dielectric reflection principle) which dictates that, with the product of thickness and refractive index of a dielectric layer interposed between two layers being one quarter of the wavelength of light incident on the dielectric layer and the refractive index of the dielectric layer is either higher or lower than the indices of refraction of the layers on both sides thereof, then the rays of light reflected on two interfaces between the dielectric layer and the interposing layers have the same phases and hence reinforce each other. Thus, the dielectric reflective film, that includes the dielectric layers designed so as to reflect the light of substantially all wavelengths in the visible region, functions as a reflective film that effects mirror reflection for visible light with reflectivity of, for example, about 80% or higher. The dielectric material usually comprises a first polymer and a second polymer

having a refractive index different from that of the first polymer, and does not include an electrically conductive metal.

The external reflecting device or the light sources provided with a built-in reflecting device of the prior art described above, however, have such problems as described below. That is, the light source provided with a built-in reflecting device has reflective layers disposed therein, and therefore does not allow it to easily change the directivity of radiation and the range of illumination in accordance to the operating conditions. In the case of the external reflecting device, on the other hand, it is relatively easy to change the directivity of radiation in accordance to the operating conditions, although the reflecting device is bulky and therefore it is difficult to use the reflecting device at a place where sufficient space cannot be secured while meeting the operating conditions. Also the directivity of radiation is uniquely determined by the design of the reflecting device, and therefore cannot be changed after installation.

Although it is known to use the dielectric reflective film as described above as a material to constitute the reflective surface of an external reflecting device (such as a reflector disposed at a predetermined distance from a light source, namely being separated by a body of air), no means has been suggested for easily changing the directivity of radiation in accordance to the operating conditions and for effectively improving the intensity of light radiated by the light-emitting apparatus.

Accordingly, the present invention provides a light reflective film capable of easily controlling the directivity of radiated light and the range of illumination in accordance to the operating conditions, and also capable of effectively increasing the intensity of the light emitted by the light-emitting apparatus, even in a place where sufficient space for the installation of the external reflecting device cannot be secured.

SUMMARY OF THE INVENTION

The present invention further provides a light-emitting apparatus capable of effectively increasing the intensity of radiated light by using the light reflective film described above.

In one aspect, the present invention provides a light reflective film product as claimed in claim 1.

In another aspect, the present invention provides a light-emitting apparatus as claimed in claim 2.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross sectional view showing one preferred embodiment of the light-emitting apparatus according to the present invention;

Fig. 2 is a cross sectional view showing one preferred configuration of the light reflective film according to the present invention;

Fig. 3 is a cross sectional view showing another preferred configuration of the light reflective film according to the present invention; and

Fig. 4 is a graph showing the results of evaluating directivity of radiation from the light-emitting apparatus according to the present invention, with the angle of rotation being plotted along abscissa and the luminance being plotted along ordinate.

DETAILED DESCRIPTION

First, an operation of the present invention will be described to assist in better understanding of the present invention.

The light reflective film according to the present invention comprises a dielectric light reflective layer having a light reflective surface opposing a light emitting surface of a light source, and a light transmittive adhesive layer intimately contacted with the reflective surface of the dielectric light reflective layer. Accordingly, it is very easy to dispose the light reflective film so that desired range of illumination (angle of radiation) and directivity of radiation are obtained at a given place of forming the light-emitting apparatus. That is, what is required for installing the light reflective film is only to put (adhere) the light reflective film of the present invention in intimate contact with the light-emitting surface of the light source via a layer of the light-transmittive adhesive so as to cover a part of the light-emitting surface over a predetermined area of coverage. This makes it possible to effectively increase the intensity of the light radiated through the remaining part of the light-emitting surface of the light source, and easily and freely control the range of radiating the light and directivity of radiation.

Further, as the reflective surface disposed in close proximity of the light-emitting surface of the light source is formed from a polymer (dielectric material), high-frequency current can be reliably prevented from leaking due to earth leakage or short circuiting, even in case the light source is a high frequency current light emitter such as fluorescent tube, cold cathode tube or the like.

Furthermore, the arrangement of the reflective surface of the light reflective film being intimately contacted with the light-emitting surface of the light source via the adhesive layer has such effects as described below. Light emitted from the light source and incident on the surface of the dielectric light reflective layer is partly reflected on the surface, with the rest entering the dielectric light reflective layer to be reflected in the layer and emerging back to the outside through the surface, so that the light is reflected totally through these reflecting actions combined (dielectric reflection principle). At this time, in case the surface of the dielectric light reflective layer constitutes an interface with air (refractive index =1), the portion of light emerging back from the inside of the layer to the outside through the surface is reflected on the interface with air and returns into the layer. The light that has returned into the dielectric reflective layer attenuates in the layer and, as a result, the intensity of light reflected on the dielectric reflective layer decreases thus leading to a decrease in the intensity of light radiated by the light emitting apparatus. In case the dielectric reflective layer has an interface with an adhesive layer instead of air,

however, light returning into the layer can be minimized thereby effectively increasing the intensity of light radiated by the light-emitting apparatus. This is because the adhesive (i.e., polymer) has a higher refractive index than that of air.

The light reflective film according to the present invention preferably includes further a diffusive reflection layer intimately contacted with the surface opposing the reflective surface of the dielectric reflective layer. This configuration makes it possible to direct the reflected light toward the illuminated area without substantially changing the spectrum of the light, even when the light emitted by the light source includes wavelengths that cannot be effectively reflected by the dielectric reflective layer only and are transmitted therethrough.

Then, the light reflective film and the lightemitting apparatus according to the present invention as well as constituent elements thereof will be described below.

A light reflective film according to one embodiment of the present invention comprises a reflective layer 3 and a light-transmittive adhesive layer 2 as shown in Fig. 1. The light reflective film 4 can be bonded securely onto a part of a circumferential surface (light-emitting surface) of a light source 1 via the adhesive layer 2, thereby forming a light-emitting apparatus 10. Thus, it is very easy to cover the circumferential surface of the light source 1 with the light reflective film 4 intimately contacted therewith over a predetermined area of coverage in situ as the light source 1 is installed, thereby increasing the intensity of the light (radiation) emitted through the remaining part of the circumferential surface not covered with the light reflective film and achieving desired directivity of radiation. The light reflective film of the embodiment shown in the drawing has a substantially rectangular shape. In this case, the light reflective film is disposed in such a manner that the longer side of the rectangle is substantially parallel to the longitudinal direction of the light source 1. The shape of the light reflective film is not limited to that described above, and may be freely selected according to the fields of use and purposes. For example, parallelogram, trapezoid, circle, ellipse or a polygon having geometrical regularity may also be employed.

The proportion of the area covered by the light reflective film is usually in a range from 1 to 95% of the total area of the circumferential surface (light emitting surface), preferably from 12 to 85%, and more preferably from 25 to 75%. Less coverage area may lead to failure in effectively improving the directivity of radiation and greater coverage

area makes the range of illumination (radiation angle) too narrow, in either case the light-emitting apparatus may have less practical usefulness. In case the light source such as fluorescent tube has a circular cross section, an angle of covering with the light reflective film (winding angle) is in a range usually from 5 to 355°, preferably from 45 to 315°, and more preferably from 90 to 270°. Less coverage angle may lead to failure in effectively improving the directivity of radiation and greater coverage angle.makes the range of illumination (radiation angle) too narrow, in either case the light-emitting apparatus may have less practical usefulness. The "coverage angle" is defined as the angle subtended at the center by the arc formed by the light reflective film coverage in the cross section (section perpendicular to the longitudinal direction) of the light source.

While the light reflective layer normally comprises a dielectric reflective layer, it may also include the diffusive reflection layer described above or other layer in addition to the dielectric reflective layer. The light reflective surface that opposes the light-emitting surface of the light source is, on the other hand, formed from the light reflective surface of the dielectric reflective layer, while the adhesive layer needs to be intimately contacted with the light reflective surface of the dielectric reflective layer. Reflectivity of the dielectric reflective layer is usually 70% or higher, preferably 80% or higher, and more preferably 90% or higher. The "reflectivity" used in this specification is measured by means of a spectrophotometer over an entire range of wavelengths from 450 to 750 nm. Thus, "reflectivity of 70% or higher" means that there is no wavelength which is reflected with reflectivity less than 70% within the range from 450 to 750 nm.

Transmittance of light through the adhesive is usually 70% or higher, preferably 80% or higher, and more preferably 90% or higher. The "transmittance,, referred to in this specification is measured by means of a spectrophotometer over an entire range of wavelengths from 450 to 750 nm. Thus "transmittance of 70% or higher" means that there is no wavelength which is transmitted with transmittance less than 70% within the range from 450 to 750 nm.

The total thickness of the light reflective layer is not specifically limited as far as the effect of the present invention is not adversely affected. However, it is preferred that the light reflective film has higher flexibility in order to easily bond it on the curved light-emitting surface. From such a point of view, the thickness is usually from 1 to 500 µm, and preferably from 10 to 300 µm. In addition, the thickness of the adhesive layer is not

specifically limited as far as the effect of the present invention is not adversely affected. However, it is preferred that higher adhesive power is provided in order to easily bond the light reflective film onto the curved light-emitting surface. From such a point of view, the thickness is usually from 5 to 200 μm, and preferably from 10 to 100 μm.

Planar dimensions of the light reflective film are preferably determined so that the entire profile of the light-emitting apparatus incorporating the light reflective film does not become bulky. For example, the planar dimensions of the light reflective film are determined so that the entire light reflective surface of the light reflective film is intimately contacted with the light-emitting surface of the light source (namely, there is no redundant portion that is not intimately contacted with the light-emitting surface). The adhesive layer may be applied either over the entire light reflective surface of the light reflective film or over a part of the light reflective surface. when the adhesive layer is applied over the entire light reflective surface of the light reflective film, however, an advantage as described below can be obtained. As will be described later, the dielectric reflective layer is typically formed from a polymer. Consequently, use of the light emitting apparatus incorporating the light reflective surface over an extended period of time may likely to cause deformations such as shrinkage or wrinkle due to the heat generated by the light source. However, when the entire light reflective surface of the light reflective film is securely bonded onto the light emitting surface, such deformations can be effectively prevented from occurring even when intimately contacted with the light source that generates heat.

According to one embodiment of the present invention, as described above, the reflective layer comprises the dielectric light reflective layer. The dielectric light reflective layer is preferably includes a first set composed of a plurality of layers comprising a first dielectric polymer and a second set composed of a plurality of layers comprising a second dielectric polymer which has a refractive index of different from that of the first dielectric polymer, the first polymer layers and the second polymer layers being laminated alternately. Specifically, at least either one of the first set and the second set includes a quarter wavelength layer wherein the product (nd) of thickness (d, in nm) and refractive index (n) is one quarter of the wavelength of the reflected light, making use of the effects of the dielectric reflection principle. Since the dielectric light reflective layer is formed by laminating plural kinds of polymer as described above, the dielectric light

reflective layer can be easily processed such as cutting and has satisfactorily flexibility suitable for bonding onto a curved surface.

Such a dielectric reflective layer as described above comprises, for example, a dielectric reflective film. Such a dielectric reflective film can be formed by the methods such as:

(a)a method of coating a flexible transparent film with layers of a dielectric material (polymer) in a multiple coating process; or

(b)a method of forming a multiple layer film by co-extrusion process using a dielectric material made of a polymer. A method of producing such a dielectric reflective film is disclosed, for example, in Japanese National Publication (Kohyo) No. 9-506837 (T2) cited above.

Polymers which can be utilized as the dielectric material are light-transmittive polymers having a refractive index of 1.1 or higher and, for example, polyester (e.g. polyethylene naphthalate, polyethylene terephthalate, copolymer of ethylene phthalate-ethylene terephthalate, etc.), acrylic polymer (e.g. polymethyl methacrylate, copolymer of methyl methacrylate and the other (meth)acrylate, etc.), polystyrenic polymer (e.g. polystyrene, copolymer of styrene and butadiene, copolymer of styrene and acrylonitrile, etc.), fluoropolymer (e.g. polyvinylidene fluoride, ethylene fluoride-propylene fluoride copolymer, etc.) and polymers such as polyethylene, polypropylene, ethylene-acrylic acid copolymer, ethylene-vinyl acetate copolymer, polyvinylidene chloride, polycarbonate, polyurethane, epoxy resin, etc. can be preferably used. The dielectric reflective film is preferably formed as a multi layer polymer film by the method (b) mentioned above. This is because the above method (b) has a good processability and therefore the dielectric reflective film of the present invention can be easily produced.

The dielectric reflective film is formed, for example, by laminating a first layer including one or more kinds of dielectric polymer as described above and a second layer including a dielectric polymer in the similar manner. Substantially, all of the layers have a thickness of smaller than 1 μm and a plurality of layers having different thicknesses are included so that the dielectric reflection effect described previously can be obtained. The refractive index of each layer is usually

1.1 or higher, and preferably in a range from 1.2 to 2.8.

A difference (An_1n_2) between the refractive index n_2 of the first layer and the refractive index n_2 of the second layer is usually in a range from 0.05 to 1.5, and preferably from 0.1 to 1.0. In case the layers include polymers, the layers are preferably biaxially oriented, because this improves the reflectivity effectively.

In addition to the two kinds described above, one or more dielectric polymer layers may be added to form a laminate. The dielectric layers may also contain additives such as ultraviolet absorbers, antioxidants, mildew proofing agents, rust preventives, moisture absorbents, colorants, phosphorescent materials, surfactants, etc. as far as the effect of the present invention is not adversely affected. Further, a dielectric reflective film made by applying another layer such as a light-transmittive protective layer or a colored layer on the front surface, back surface or both surfaces of the dielectric reflective film can also be used as the dielectric light reflective layer as far as the effect of the present invention is not adversely affected. The another layer used herein usually has a thickness in a range from 0.1 to 100 μm. Furthermore, the dielectric reflective film may also be a light reflective film having a polarizing effect.

According to one preferred embodiment of the present invention, the light reflective layer is composed of a laminate of layers comprising a dielectric light reflective layer and a diffusion reflection layer intimately contacted with a surface (laminating surface) opposite to the light reflective surface (surface opposing the light source) of the dielectric light reflective layer. The diffusion reflection layer is formed by, for example, coating the laminating surface of the dielectric light reflective layer with light reflective coating material comprising a binder and light-diffusing particles dispersed in the binder. The coating material may be coated by using, for example, a conventional coating device such as knife coater, bar coater or the like.

As the binder, a conventional polymer or resin for coating can be used and examples thereof include (meth)acrylate copolymer, polyurethane resin, silicone polymer (including silicone-polyurea copolymer), fluoropolymer, vinyl chloride polymer, epoxy resin and the like. The higher the light transmittance of the above polymers, the better. The light transmittance is usually 80% or higher.

The light-diffusing particles are, for example, white inorganic particles such as titanium oxide and barium sulfate; glass particles; ceramic particles; organic polymer particles; air bubbles and fine metal particles. The light-diffusion particles may be either

solid or hollow. The diameter of the light-diffusion particles is usually in a range from 0.05 to 10 μm.

The thickness of the diffusion reflection layer is determined so as to achieve the effect described above, and is usually in a range from 10 to 100 am. Further, the mixing ratio of the light-diffusion particles in light reflective paint is from 20 to 800 parts by weight based on 100 parts by weight of the binder (solid content).

The adhesive preferably has as high transparency as possible, and the refractive index thereof is usually in a range from 1.3 to 1.8, and preferably from 1.4 to 1.6. The type of the adhesive is preferably pressure-sensitive type (pressure-sensitive adhesive), hot-melt type, heat sensitive type (heat-activatable), solvent-activatable type, or curing type. The curing type adhesive is preferably cured by heat, moisture or radiation (e.g. ultraviolet ray, etc.).

Preferred adhesive is an adhesive containing a silicone polymer (including silicone-polyurea copolymer), acrylic polymer, polyurethane, rubber polymer (e.g. natural rubber, styrenic copolymer, etc.). Among them, the acrylic adhesive is preferably used, because it can exhibit high transparency, high adhesion and high refractive index (usually 1.4 or higher) at the same time.

The acrylic polymer is a polymer obtained from a reaction product containing an acrylate monomer having 4 to 14 carbon atoms (e.g. isooctyl acrylate, butyl acrylate, 2-ethylhexyl acrylate, etc.) and an optionally used (meth)acrylate monomer having a polar group (e.g. (meth)acrylic acid, carboxylalkyl (meth)acrylate, hydroxyalkyl (meth)acrylate, N,N-dialkylacrylamide, etc.), or a composition containing such a polymer.

The adhesive layer can be formed by, for example, coating a coating solution containing a polymer or a polymer composition on the dielectric light reflective layer. The adhesive layer may also be formed by a polymerization process (e.g ultraviolet polymerization, thermal polymerization, etc.) on the light reflective surface after application of a coating solution containing a reaction substance capable of forming a polymer upon polymerization. Alternatively, a separately produced film of adhesive on a release film may be transferred from the release film onto the dielectric light reflective layer.

The adhesive is usually colorless, but may be colored by containing colorants such as pigments, dyes, etc. as far as the effect of the present invention is not adversely affected.

Further, the adhesive can also contain additives such as ultraviolet absorbers, antioxidants, mildew proofing agents, rust preventives,
moisture absorbents, colorants, phosphorescent materials, surfactants, etc.

The light-emitting apparatus according to the present invention is provided with (a) the light source and (b) the light reflective film intimately contacted with the light-emitting surface of the light source via a layer of the adhesive layer so as to cover a part of the light-emitting surface of the light source. For the light source of the light-emitting apparatus according to the present invention, fluorescent tube, thermionic cathode tube, cold cathode tube, neon tube, xenon tube or the like may be used. Output power of the light-emitting apparatus is usually from 2 W to 200 W. There is no restriction on the shape of the light source which may be straight (linear), circular (including ellipse), bent lines of letter or other shape, or the like. In the light-emitting apparatus of the present invention, the entire reflective surface of the light reflective film can be intimately contacted with the light-emitting surface of light source. In this case, since the profile and the dimensions of the light-emitting apparatus are substantially the same as those of the light source in use, problems due to bulkiness of the an apparatus including the external reflecting device of the prior art can be easily solved.

The light-emitting apparatus according to the present invention can be used as an indoor illumination, desk-top illumination, downlight illumination for display such as show case, light box for illuminating right below, light box of edge light type, neon sign, inside illuminated signboard or the like.

For example, the light-emitting apparatus can be applied to light box for illuminating light below direction which will be described below. The light emitting apparatus (light source) is disposed in a light guiding space of a box (normally rectangular parallelepiped) having a cavity (light guiding space). The box normally comprises a top plate having a window made of a light-transmittive material, opaque side plates (four plates) and a bottom plate. Inside (surfaces opposing the light guiding space) of the side plates and the bottom plate are covered with a light-reflecting material. The top plate is preferably a white and semitransparent diffusive transmission plate. The light emitting apparatus is disposed between the top plate and the bottom plate. In order to radiate light with desired directivity, the light-emitting apparatus is made by putting the light reflective film of the present invention into intimate contact with the light source. In this case, proportion of

area covered by the light reflective film is usually in a range from 10 to 50%. Number of light-emitting apparatuses (light sources) disposed is usually from 1 to 10, and preferably from 2 to 6. The light-emitting apparatus is disposed in parallel to the bottom plate and/or the top plate. When a plurality of light-emitting apparatuses are used, the light-emitting apparatuses are usually disposed in parallel to each other.

The light-reflecting material that covers the inner surfaces of the side plates and the bottom plate is preferably a non-conductive material, and the diffusive reflection layer described above is usually used. However, it is preferable that a dielectric reflective film is used in order to effectively increase the intensity of light radiated through the light window. The inner surfaces of the side plates and the bottom plate can be rendered good reflectivity by using the light reflective film of the present invention made by using the dielectric reflective film having light reflective surfaces on both sides, and intimately contacting the light reflective film via the adhesive layer.

It is preferable to design the shape and dimensions of the light reflective film that constitutes the light emitting apparatus so that almost all light emitted by the light-emitting apparatus is directed toward the bottom plate and the side plates and a part of the light is directed toward the top plate too. This configuration makes it possible to increase the brightness uniformly over the light window plane. For example, it is preferable to make a plurality of slits (notches) 14 on the two longer sides (both edges in the direction of width) of the light reflective film 4 having substantially rectangular shape, as shown in Fig. 2 and Fig. 3. Shape of the slit is preferably a polygon such as triangle and rectangle, circle, ellipse or those based on shapes generated by regular combination of a plurality of curves as shown in the drawings. Maximum depth of cutting from the edge of the longer side of the light reflective film (maximum size of slit from the edge to the inside of the light reflective film) is usually from 2 to 20 mm, and preferably from 3 to 10 mm. Distance between adjacent slits (distance between centers of slits in the direction along the longer side of the light reflective film) is usually from 2 to 20 mm, and preferably from 3 to 10 mm, although this may be varied depends on the depth of slit. Although the slits have substantially the same shape, plurality of slits having different shape and/or dimension may be combined depending on the application.

The light box for illuminating light below direction as described above is capable of improving the luminance and unevenness of luminance over the light window compared to the prior art.

Examples

The present invention will be further described referring to the following examples thereof. Note that the present invention should not be limited to these examples.

Example 1

(1) Formation of light reflective film:

First, a dielectric light reflective film to be used as the dielectric light reflective layer was produced. The dielectric light reflective film was made by the method disclosed in Japanese National Publication (Kohyo) No. 9-506837 (T2) mentioned previously. Two polymers forming the alternating layers are polymethyl methacrylate and copolyester of ethylene naphthalateethylene terephthalate. The dielectric light reflective film had reflectivity of about 80 to 100% (at 450 to 750 nm) and a thickness of about 70 μm.

Then, the light reflective film of this example was produced by laminating an acrylic pressure-sensitive adhesive sheet having a thickness of 80 μm (light transmittance: about 98%) on the light reflective surface of the dielectric light reflective film. The light reflective film of this example showed good flexibility. The light reflectivity and the light transmittance were both measured by using an automatic recording spectrophotometer "type U-4000" manufactured by Hitachi Corp.

(2) Production of light-emitting apparatus:

The light reflective film of this example was cut to the predetermined dimensions and shape, which was then manually bonded on the circumference of a fluorescent tube, "PalucTm Day FL-20 SS.EX-D/18" manufactured by Matsushita Electric Industrial Co., Ltd. With a predetermined coverage (winding) angle, securing on the light-emitting surface of the fluorescent tube, thereby forming a light-emitting apparatus of this example.

In this example, light reflective films of three different dimensions were produced, in substantially rectangular shapes of length substantially the same length as that of the fluorescent tube and such widths as the entire light reflective surface makes intimate

contact over three different coverage angles (90°, 180°, 270°), thus making three kinds of light-emitting apparatuses. These light-emitting apparatuses could be easily produced in all cases of different coverage angles. (3)

The directivity of radiation from the light emitting apparatus was measured as described below. The light-emitting apparatus was turned in steps of 5° about the axis along the longitudinal direction of the fluorescent tube, while measuring the luminance of illumination at each angle by means of a luminance meter (BM-7, manufactured by Topcon Co., Ltd.), and the directivity as evaluated according to the results of measurement. These results are shown in Fig. 4 where the angle of rotation is abscissa and the luminance is plotted Fig. 4. Curve I shows a comparative light reflective film of this example. Curve II shows a case of winding over an angle of 90 °. Curve III shows a case of winding over an angle of 180'. Curve IV shows a case of winding over an angle of 270°. Angle "O" was defined herein as a position where the luminance meter and the light-emitting apparatus were arranged so that a line connecting the central point of the remaining portion of the fluorescent tube not covered by the light reflective film in the circumferential direction on the circumference and the central point of the circular section and the light receiving plane of the luminance meter intersect at right angles, in the cross section (circular) of the light-emitting apparatus (fluorescent tube) perpendicular to the longitudinal in the graph of plotted along along ordinate. In case where the was not used, an angle of 90°, a direction thereof. The graph shows that, as the coverage angle increases, the range which can be illuminated decreases but the luminance increases. That is, by using the light reflective film of the present invention, the directivity of radiation can be improved easily and effectively. The distance between the light receiving plane of the luminance meter and the light-emitting surface of the light-emitting apparatus was set to about 1 M.

Example 2

A light reflective film of this example was produced in the same manner as in Example 1, except that a diffusive reflection layer was further included that was intimately contacted with a surface opposite to the light reflective surface of the dielectric light reflective film. The diffusive reflection layer was formed by directly coating white light reflective paint containing barium sulfate (New LP Super, manufactured by Toyo Ink Co.,

Ltd.) onto the dielectric light reflective film and dried so that the thickness becomes 50 μm after drying. This light reflective film was used to produce the light-emitting apparatus in the same manner as in Example 1, and directivity was evaluated. In this example, too, directivity of radiation could be easily and effectively improved similarly to Example 1.

Although the reflective film of Example 1 showed reflectivity in a range from about 65 to 80% for light in a wavelength range from 400 to 450 nm, reflectivity was improved in Example 2 to a range from about 90 to 98% for light in a wavelength range from 400 to 450 nm due to the addition of the diffusive reflection layer (measured by the spectrophotometer described previously). Thus, it was found that reflected light could be directed toward the illuminated area without hardly changing the spectrum of the light, even when the light emitted by the light source ranges from 400 to 450 nm.

<u>Comparative Example 1</u>

A light-emitting apparatus of this example was produced in the same manner as in Example 1, except that a dielectric light reflective film was wound around the light-emitting surface of a fluorescent tube without using an adhesive. A coverage (winding) angle was set to 90°, 180° and 270°, and the dielectric light reflective film was wound around the fluorescent tube to keep the light-emitting surface and the dielectric light reflective film as close to each other as possible, although there is a layer of air therebetween. As a result, it was found that luminance was reduced by about 3.5% lower in comparison with Example 1. This showed that improvements in both luminance and directivity can be effectively achieved by using the light reflective film of the present invention and putting the light emitting surface of the light source and the light reflective surface of the dielectric light reflective film into intimate contact with each other.

<u>Example 3</u>

The light box for below direction illumination was formed by using the light-emitting apparatus of the present invention in the following manner.

First, the light-emitting apparatus of this example was produced by putting the light reflective film made in Example 1 in intimate contact with a fluorescent tube incorporated in a commercially-available light box (Medical X-ray observation Apparatus, manufactured by Kihara Medical Industry Co., Ltd.). In this example, a rectangular (about

420 mm in length, about 15 mm in width) light reflective film was produced, and then a plurality of slits were cut on two longer sides thereof. Each slit has substantially a shape of isosceles triangle, while the maximum depth of cutting from the edge of the longer side of the light reflective film was 5 mm, and the distance between adjacent slits was 5 mm. The proportion of the covered area was about 14% (see, Fig. 2).

Then, four light-emitting apparatuses of this example were disposed in the light guiding space of the light box, in parallel to the top plate with the four being parallel to each other, thereby forming the light box for illuminating right below of this example. The light-emitting apparatus was disposed so that the light emitting surface thereof (the portion not covered with the light reflective film) opposed the bottom plate, while most of light from the light-emitting apparatus was directed toward the bottom plate and the side plates, and a portion of the light was directed toward the top plate. The top plate was made of a diffusive-transmitting acrylic plate of milky white color and the inner walls of the light box (the bottom plate and the four side plates) were coated with diffusive-reflection paint of white color.

Luminance of the light window of the top plate of the light box for illuminating right below at the front thereof was measured by using a luminance meter LS-110 manufactured by Minolta Corp. Average luminance of 16 measuring points was 840 cd/m^2 and unevenness in luminance (minimum value/maximum value) was 65%. When measured without using the light reflective film of the present invention, the average luminance was 954 cd /m^2 and unevenness in luminance was 58%. This shows that unevenness in luminance can be improved without significantly decreasing the luminance, by replacing the light source of an ordinary light box with the light emitting apparatus of the present invention. The distance between the light receiving surface of the luminance meter and the light window surface of the lightbox was set to about 1 m..

<u>Example 4</u>

The light box for below direction illumination of this example was produced in the same manner as in Example 3, except that the light reflective surface of the dielectric light reflective film used Example 1 was bonded onto the inner walls (bottom plate and four side plates) of the light box toward the inside of the light guiding space.

The luminance of the light window of the top plate of the light box for illuminating right below at the front thereof was measured in the same manner as in Example 3. As a result, the average luminance was 1698 cd /m^2 and the unevenness in luminance was 83%. This shows that the luminance and unevenness in luminance can be significantly improved by replacing the light source of an ordinary light box with the light-emitting apparatus of the present invention and covering the inner walls of the light guiding space with the dielectric light reflective film. When measured without using the light reflective film for covering the light source in the light box of this example, the average luminance was 1902 cd /m^2 and the unevenness in luminance was 80%.

Example 5

A light reflective film of this example was produced in the same manner as in Example 2, except that a blue light-transmittive colored layer was disposed between the adhesive layer (acrylic pressure-sensitive adhesive) and the dielectric light reflective film. That is, the dielectric light reflective layer of this example was composed of the dielectric light reflective film and the colored layer. The colored layer is a coated film of the following composition, and the thickness was 0.5 μm. Composition of light-transmittive colored layer: Heliogen Blue L670OF (blue pigment available from BASF Co.)100 parts by weight Disperbyk 161 (dispersant available from BYK-Chemie Co.)15 parts by weight CARBOSET GA1162 (acrylic polymer available from BF Goodrich Co.)163 parts by weight SU8 (epoxy crosslinking agent available from Shell Chemical Co.)107 parts by weight. A light-emitting apparatus was produced in the same manner as in Example 1 by using the light reflective film of the present invention, and the directivity was evaluated. In this example, as is Example 1, the directivity of radiation could be improved easily and effectively. The radiated light color was blue (chromaticity value: x = approximately 0.276, y = 0.294). Intrinsic light color emitted by the light source (fluorescent tube) as white with chromaticity value was as follows: x = approximately 0.310 and y = 0.322. Chromaticity of the emitted light was measured by using the luminance meter (model BM-7, manufactured by Topcon Co.) mentioned previously.

The results of this example show that color of the radiated color can be changed without changing the color of the light source, in case the light reflective film of the present invention includes the light-transmittive colored layer described above. For

example, a lightemitting apparatus radiating -light of a desired color can be easily formed at the location of installing the lightemitting apparatus without need to previously produce an apparatus of the desired light color such as in the case of a neon tube.

According to the present invention, as described above, the light reflective film is provided that is capable of easily controlling the directivity of radiation and illuminating range in accordance to the operating conditions and also capable of effectively increasing the intensity of the emitted light of the light-emitting apparatus, even when at a place where sufficient space for the installation of the external reflecting device cannot be secured. Also the light emitting apparatus capable of effectively increasing the intensity of the emitted light is provided by using the reflective film described above.